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Research Paper

Design of Terry Towels: Assessment of the Effect of Weft Density and Pile Height on Fabric's Weight

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ABSTRACT:- *The aim of the present study was to determine the influence of the pile height and the weft density on the weight (mass per unit area) of terry towels. A CAD/CAM system was applied to design 9 cases of terry towels with changeable parameters of picks per centimeter and height of the loops. A controlled, single-factor experiment was performed, which included designing of the samples, production of 10 terry towels per a case and measurements of the weight after final finishing. The results obtained showed strong influence of the studied parameters on the towels weight. A regression analysis was applied to determine the effect of the input variables and to derive equation of practical use for preliminary calculations of the weight of the finished towels at the design stage. The results are of practical use for the designers, when creating new items, and for engineers, who can decrease the machine stops for checking of the required weight of the fabric.*

Keywords:- *CAD system, design and manufacturing, pile, terry towels, textiles*

I. INTRODUCTION

Terry fabrics and particularly – terry towels, are among the most frequently used textile items in the world. The weight of the terry fabrics influences their appearance and application, as well as the price calculation. The buyers control the weight of the towels and any deviation from the ordered values is a subject of sanctions. The strong global competition for high quality and low costs products require excellent organization of the technological process and precise assessment during the design stage.

Several studies have investigated different aspect of the manufacturing, finishing and application of terry towels. The technology of terry towel production was presented in details in [1]. The effect of finishing on performance characteristics of terry fabrics was studies in [2, 3]. Theoretical prediction of the porosity of terry fabrics was proposed in [4]. The effect of fibers, woven fabric's structure and finishing on handle and sorption ability of terry fabrics was studied in [5]. The comfort parameters of terry-woven structures has been identified and studied in [6]. Terry fabrics were used even for incorporation of micro capsules with essential oils [7].

The exact prediction of the weight of a terry fabric is an important part of the design of a new terry towel. It can allow permanent and error-free production process from the design stage of a new item to final labeling. The new design could require changes in the pile look, expressed in adjustment of new loop length or weft density. The combination between the loop part and the smooth part of the border makes the problems of the theoretical prediction even more difficult. However, there is a lack of information on this topic of practical use. Such information is beneficial for the development of new towels as look and pattern, as well as for the uninterrupted work of the weaving machines, without the need of cutting the cloth for additional measurement of its weight.

The present study focused on the assessment of the effect of weft density and the loop height on the weight of terry towels. Nine types of terry towels were designed under controlled conditions to assess the influence of the pile height and the weft density on the weight of the finished towels. Regression analysis was applied to derive dependence between the three variables: height of the loop, weft density and mass per unit area of the fabric. The presented results and analysis are of practical use for designing of terry towels.

II. MATERIALS AND METHODS

2.1 Materials

Three different designs of woven fabrics were created with a size of 70x140 cm, pile area and a border of 8 cm: B (Bulgaria), C (Creative) and F (Fashion).

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It is a common practice nowadays a logo or an inscription to be inserted in the border. This requires more colors to be used in the border part, while the pile part is woven with raw yarns and the whole towel is dyed after weaving.
Four types of yarns were included in the design f the terry towels, as summarized in Table 1.

Table 1. Data for the Threads Used

Type	Material	Finishing	Linear density
Ground warp	100% cotton	raw	30x2
Pile warp	100% cotton	raw	25x2
Weft	100% cotton	raw	40
Border weft	80/20% cotton/polyester	colored	40

2.2 Methods

Only one parameter was foreseen to be changed in the structure of the samples: the loop height (V_h) or the weft density (P_{wf}). Each of the samples groups was designed with different weft density: Samples F with 16 picks/cm; Samples B with 17 picks/cm; and Samples C with 18 picks/cm. Three different pile heights, namely 7.5 – 8.5 – 9.5 mm were used for the towels in each group.

A polyester thread of different color was included in the border of every terry towel so as the samples to be discernible after finishing and sewing.
Dornier air-jet terry jacquard weaving machine was used for the production. The ground warp had 2994 threads, the pile warp had 2598 threads and the total amount of threads in one terry towel was 866.
Table 2 summarizes the investigated cases.

Table 2. Investigated Cases

Sample	Pile height H_p, mm	Weft density, P_{wf}, pics/cm
F1	7.5	16
F2	8.5	16
F3	9.5	16
B1	7.5	17
B2	8.5	17
B3	9.5	17
C1	7.5	18
C2	8.5	18
C3	9.5	18

Part of the design of Samples F is shown in Fig. 1 together with the weave. Figure 2 presents another screenshot of the towel design, with a detail from the towel border.

2.3 CAD Software

EAT DesignScope victor CAD Software was used for designing the samples. The software modules allow to control the design process at any stage: the design at the beginning, within the production stage and at the end of the manufacturing. The simulation of the terry towel allowed to assess the whole complex process of designing. Virtual models of the terry towels, involving linear density of the yarns, materials, colors and thread sequences, were created. Figures 1-2 show the ability of the software to visualize the different parts of the fabric, to isolate them to be edited, or the whole multi-segment pattern to be manipulated.

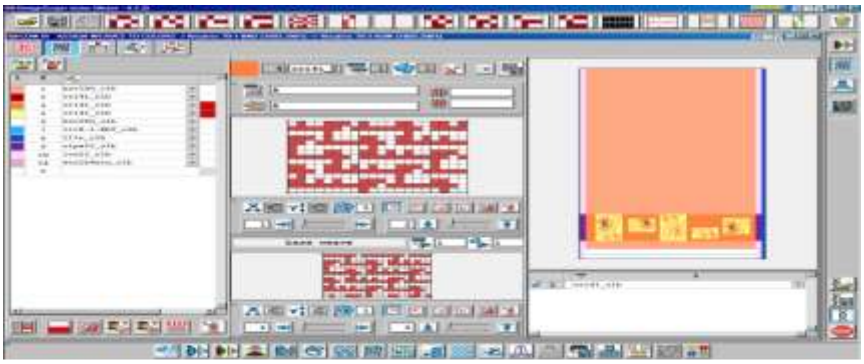

Fig. 1. Design of the border of Samples F with the respective weave pattern

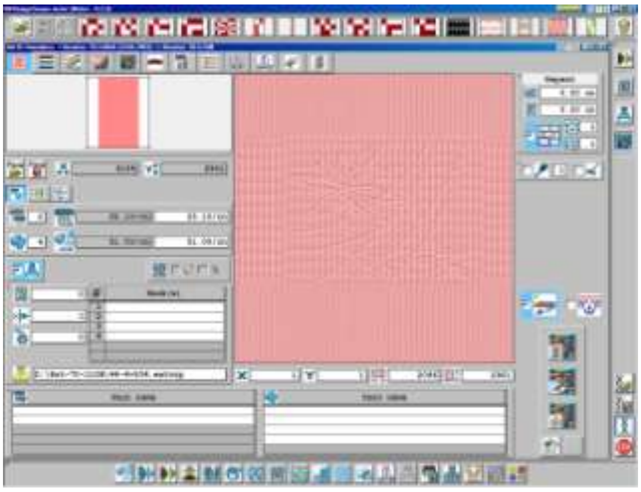

Fig. 2. A detail of the border; Samples F

Figures 3-5 show the virtual designs of the developed terry towels, Samples F, B and C respectively.

Fig. 3. Virtual model of Samples F (16 pics/cm)

Fig. 4. Virtual model of Samples B (17 pics/cm)

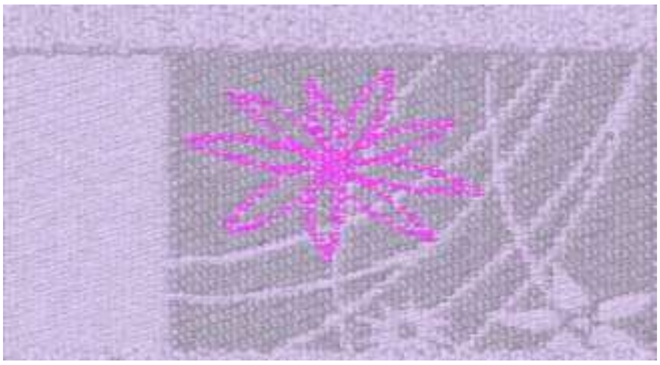

Fig. 5. Virtual model of Samples C (18 pics/cm)

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2.4 Finishing of the raw towels

Finishing is an inseparable part of the production of terry towels. The samples pass through various processing stages and the difference in the weight of the fabric in the raw and in the ready state is between 7% and 10%, depending on the treatment (bleaching and dying) [8].

The finishing was done in ECOMASTER F dyeing apparatus. The finishing process included a pretreatment of the samples: boiling and semi-bleaching in a single bath. The real dyeing involved treatment with saline at 60º for 20 minutes, processing in a dye solution with reactive dyes and fixation. The final finishing included several hot washes and surface activation for best hand and hydrophilic abilities. The last processes in the terry towel production were drying and making up.

2.5 Determination of the weight

The weight (or mass per unit area) of the samples was measured after 48 hours of conditioning in standard climatic conditions (20 ^{o}C; 65% RH). The measurements were done in the middle of a fold in two towel [8]. The width W_t of the towel was measured as the distance between the edges in the direction, perpendicular to the line of production, including the selvage. The length L_t of the towel was determined as the distance between the edges in the direction of the warp threads. The mass of the towel m_t was measured with an electronic balance. Finally, the weight (mass per unit area) m_s of the towel was determined, according to Eq. (1):

$$m_s = \frac{m_t}{W_t L_t},\ g/m^2 \qquad (1)$$

III. RESULTS AND DISCUSSION

The experimental results from the determination of the weight of each sample (average value of 10 readings) are presented in Table 3.

Statistical analysis was applied to the results in Table 3, for a 95% confidence level. The confidence interval (CI) of each case was determined and presented in Table 3. The standard error was from 0.10 to 0.60 %, which is within the allowed deviation range when the product is sold.

Figure 6 visualizes the results from determination of the weight of the terry towels.

Table 3. Experimental Results for the Weight of the Terry Towels

Case	$\square_{wf}$, picks/cm	H_p, mm	Terry towel weight m_s, g/m^2										Terry towel weight CI g/m^2
			Single samples										
			1	2	3	4	5	6	7	8	9	10	
F1	16	7,5	424	421	419	419	421	424	421	419	421	419	**419.4 – 422.2**
F2	16	8,5	439	448	444	447	453	453	447	448	447	444	**444.2 – 449.8**
F3	16	9,5	480	479	478	480	479	479	479	480	478	480	**478.5 – 479.7**
B1	17	7,5	435	436	440	437	440	436	435	439	440	437	**436.1 – 438.9**
B2	17	8,5	469	469	471	473	471	473	470	470	474	474	**471.4 – 470.0**
B3	17	9,5	505	515	510	503	505	500	505	500	503	504	**501.0 – 508.0**
C1	18	7,5	457	454	463	454	455	460	454	458	460	460	**455.3 – 459.7**
C2	18	8,5	491	492	494	492	492	492	491	490	492	492	**489.7 – 493.9**
C3	**18**	**9,5**	**524**	**524**	**522**	**523**	**524**	**520**	**523**	**520**	**523**	**520**	**521.1 – 523.4**

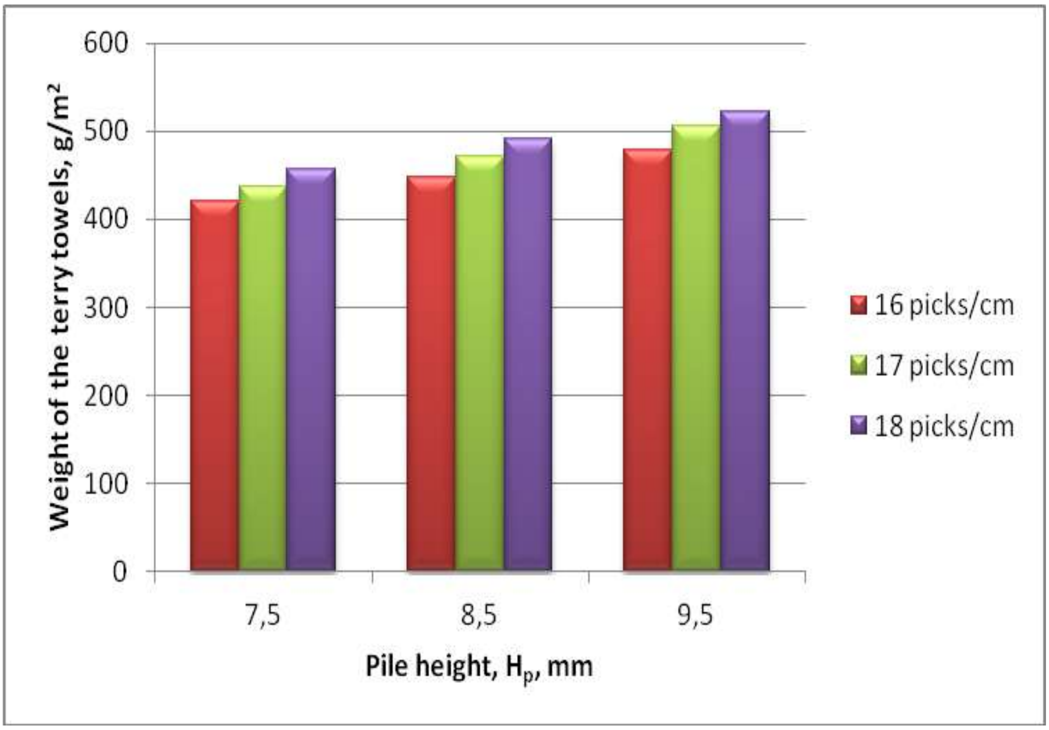

Fig. 6. Weight of the terry towels in a function of the weft density and the pile height

The analysis of the results shows that when the weft density of the terry towel is constant, the increment of the pile loop height with 1 mm leads to augmentation of the mass per unit area of the towel with 30 g/m^2 (± 0.1 to 0.6%). At the same time, if the pile height is constant, the increment of the weft density with 1 pick only, leads to augmentation of the mass per unit area of the towel with 20 g/m^2 (± 0.1 to 0.6%). Taking into account the data for the yarns used, these conclusions can be of practical importance for designers when creating new terry patterns from similar yarns.

A regression analysis on the dependence between the weight of the terry towel and both the weft density and height of the pile was also performed. The R^2 value was 0.995 for 99% confidence level and the Significance F was very low ($6.53*10^{-6}$). The residuals of the two input variables showed no pattern. A regression equation for the dependence of the weight of the terry towel from the height of the pile (mm) and the weft density (picks/cm) was derived, namely:

$$m_s = -152.914 + 20{,}766P_{wf} + 31{,}783H_p \quad (2)$$

A verification of the applicability of the derived regression equation was performed. The mass per unit area of an additional sample of terry towel, produced from the same threads (see Table 1) with a weft density of 19 picks/cm and 8.3 mm height of the pile, was predicted, based on (2). The calculated weight of a towel was 505.4 g/m^2, while the real measurement (an average of 5 single readings) was 504 g/m^2. The correlation was very good.

IV. CONCLUSIONS

A CAD/CAM system was applied to design nine cases of terry towels with changeable parameters of picks per centimeter and height of the loops. A controlled, single-factor experiment was performed to assess the influence of the weft density and pile height on the weight of terry towels (70x10 cm).

The results obtained showed strong influence of the studied parameters on the towels weight. It was found that the increment of the pile loop height with 1 mm leads to augmentation of the mass per unit area of the towel with 30 g/m^2 (± 0.1 to 0.6%) and the increment of the weft density with 1 pick leads to augmentation of the mass per unit area of the towel with 20 g/m^2 (± 0.1 to 0.6%).

A regression equation was derived to be used for prediction of the weight of new towels, designed from the same yarns with different pile and weft density. The results are of practical use for engineers and designers of terry fabrics.

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